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Loss of the central visual field, or foveal scotoma, due to accidental exposure to laser light or macular disease can cause serious impairments in visually guided performance by either long lasting afterimages from visible radiation or permanent or degenerative injury to retinal cells. Foveal scotomas also interfere with normal control of eye fixations and saccades during visual tasks. Development of an electronic aid is described as a compensation for central field losses which would be suitable for vehicle and person portability. The aid is designed to compensate for performance loss expected to accompany sudden or progressive loss of central vision.

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James H. Bertera 10/15/96

Principal Investigator Signature Date

DAMD17-94-C-4068

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INTRODUCTION

Problem

Loss of foveal vision from disease or accidental exposure to bright light seriously impairs visual functions like reading and visual search. In military contexts, the widening use of lasers for sighting, range finding, and communications may produce losses in foveal vision in the form of scotomas from retinal exposure aftereffects. The associated visual impairments have been identified as a significant and evolving problem (O'Mara, Stamper, Lund, and Beatrice, 1980; Stuck, 1982; Menendez and Smith, 1990; Green, Cartledge, Cheney, and Menendez, 1991) during military operations and training. Central scotomas produce large losses in visually guided performance because central vision has the best visual resolution compared to more peripheral retina (Ludvigh, 1941). Central retina is also important in the normal reflexive pattern of eye movement which brings targets detected in the periphery to foveal retina for recognition.

The patient with a central retinal scotoma first identifies a target of interest in peripheral vision and then attempts to hold their non-seeing fovea away from or eccentric to the target so that the target remains on an area of seeing retina outside of the scotoma boundary. This eccentric eye position is maintained until the target is recognized which generally takes longer than normal because of the lower acuity and reading capacity in peripheral retina. The optimum eccentric viewing position is the area of spared retina with the highest acuity.

Several problems limit the use of unaided eccentric fixation as a compensation for foveal visual loss:

1) Scotoma fixations
2) Scotoma drift
3) Hyper-eccentric fixations after drift

The fovea is held in the abnormal eccentric position against the normal reflex pattern of peripheral to foveal fixation and this inhibition of the normal pattern of eye movements tends to break down frequently. The scotoma subject fixates the target with the scotoma area of retina (a "scotoma fixation"), following the normal reflexive pattern of peripheral to foveal eye fixation. When the subject becomes skilled at inhibiting this normal fixation reflex, another problem emerges. The eye tends to drift from its eccentric position toward the target during the lengthened eccentric fixations, ending in the target entering the scotoma boundary and disappearing. This is followed by a saccade in the opposite direction which often puts the target far eccentric of its optimum eccentric viewing position.

The image shift method addresses these limitations by automating several aspects of eccentric viewing. The patient first sets a designator on the target of interest using peripheral vision. An optional second designator is positioned at a peripheral field position so that a fixation there places the target at an optimal position outside of the scotoma boundary. Then the observer makes rhythmic normal saccades back and forth from an eccentric eye position to the designated target (See Figure 1). The periodic saccades are produced voluntarily and serve to break up drift movements, prevent hyper-eccentric fixations, and keep the target in an optimum position on peripheral retina. In the fully implemented electronic aid method, the observer deliberately fixates the target with the scotoma. At each of these "scotoma fixations" the target is obscured but the area of interest is electronically shifted to an optimum position on retina outside of the scotoma boundary.

A range of studies on low vision patients and animal studies have demonstrated the value and limitations of different unaided viewing strategies as a compensation for loss of foveal vision. Details are presented next about how the eccentric viewing process functions and how aided recovery with image shifting serves to reduce problems in patients with long lasting macular scotomas and military personnel with acute loss of vision from laser exposure.

Scotoma size and task difficulty

Relatively small central field scotomas can produce large impairments in visual search if tasks require a high degree of foveal vision (Bertera, 1988). Simulated loss of 20 minarc of the central visual field was associated with a doubling in the search time and under some conditions significant (15%) increases in eye fixation duration. It appears that task conditions which require more foveal vision, such as seeing fine detail or discriminating similar contours or letters, are more sensitive to the impairing effects of a foveal scotoma. In a study of spontaneous adaptation to a simulated scotoma in six normal subjects, there was a marked impairment in visual search if tasks required a high degree of foveal vision (Bertera, 1988). Simulated loss of 20 minarc of the central visual field was associated with a doubling in the search time and under some conditions significant (15%) increases in eye fixation duration. In general, the impairment due to the scotoma becomes statistically stronger for search time as visibility is reduced. If foveal vision is not critical to a task, a foveal scotoma has very little effect, e.g. in visual search for targets with relatively large gaps, high contrast and with small scotomas (Bertera, 1988).

Asymmetry in preferred viewing position

Subjects faced with the task of adapting top the loss of central vision sometimes position their eyes in ways which are either asymmetrical, not optimum, or seem to generate abnormal eye movements even after extensive practice. Cummings et al (1985) found that 72% of patients with a central visual loss had developed a single, strongly preferred viewing position outside of the scotoma. Timberlake, et al (1986) also determined that patients with long standing macular disease tend to use an area adjacent to the scotoma for eccentric viewing, called a preferred retinal locus (PRL). However, their PRL was not necessarily as close as possible to the foveola, i.e., their strategy did not maximize resolution.

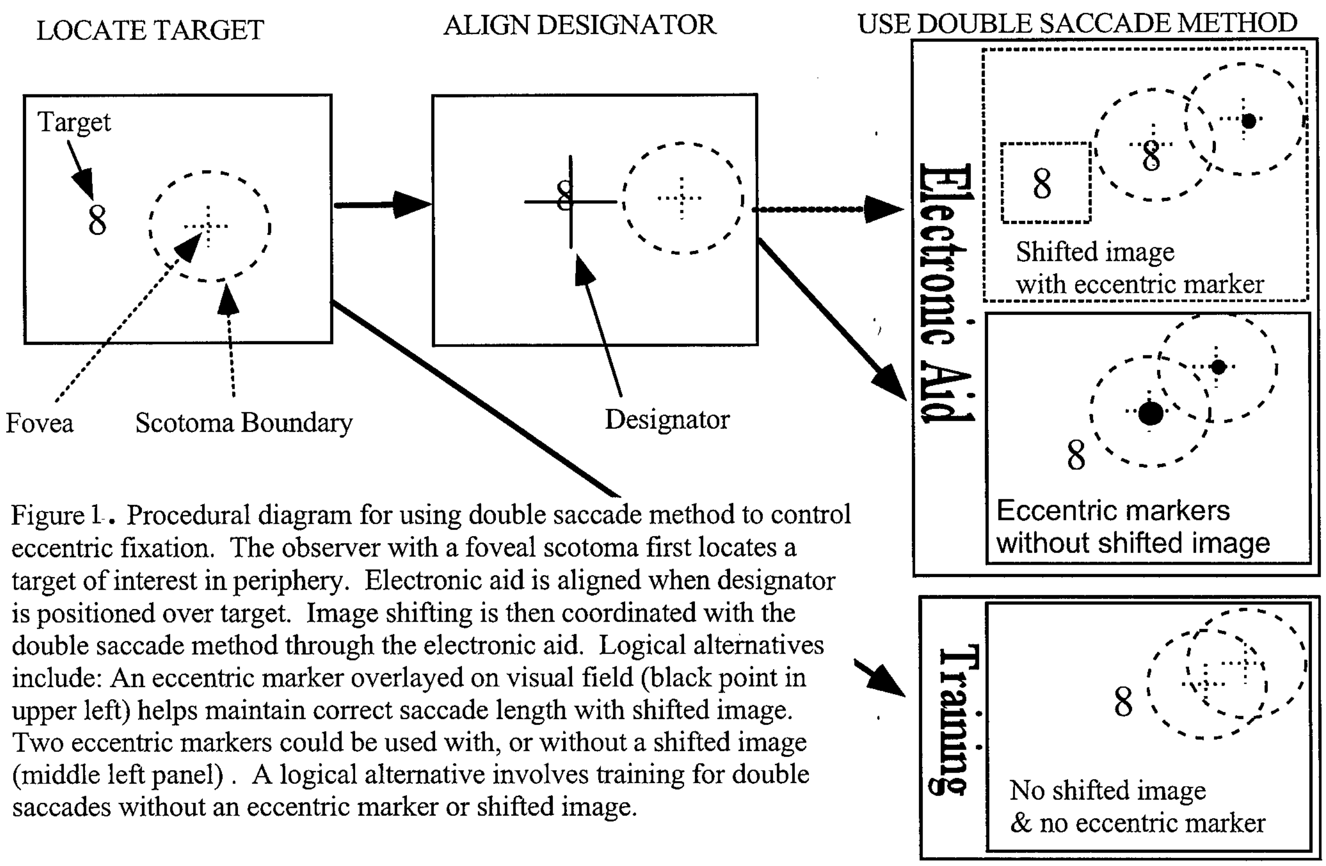


Figure 1. Procedural diagram for using double saccade method to control eccentric fixation. The observer with a foveal scotoma first locates a target of interest in periphery. Electronic aid is aligned when designator is positioned over target. Image shifting is then coordinated with the double saccade method through the electronic aid. Logical alternatives include: An eccentric marker overlayed on visual field (black point in upper left) helps maintain correct saccade length with shifted image. Two eccentric markers could be used with, or without a shifted image (middle left panel) . A logical alternative involves training for double saccades without an eccentric marker or shifted image.

White and Bedell, (1990) further determined that macular disease scotomas of 5, 10, or 20 degrees were associated with a preferred fixation area but re-referencing of eye movements to these areas was incomplete. Patients notice deficits in vision when laser treatment or disease creates visual loss on the superior retina. This makes sense since the superior retina receives much more input from below the horizon field where there are more visual signals for daily activities.

There are many asymmetrical functions and cellular architectures across the retinal field (Estes and Wolford, 1971) that might be used to explain the left right asymmetry, such as, left-right biases from reading habits, cerebral hemisphere asymmetries for input and spatial attention, and the position of the optic nerve. The studies in the present project are designed to determine if such asymmetries may interfere with the effective use of electronic image shifting as a compensation for central scotomas.

Scotoma nystagmus and drift.

During adaptation to a foveal scotoma, stable eccentric fixation and prolonged eye fixation durations may set the stage for the onset of drift or the slow phase of scotoma nystagmus. These slow movements during eccentric viewing range from drift movements, some lasting 15 seconds, to repeated nystagmus-like movements consisting of drift with a saccadic return, called scotoma nystagmus. Unlike other forms of nystagmus (optokinetic or vestibular) this "scotoma nystagmus" can be interrupted with verbal instructions to make saccades. The significance of such movements is that they redefine the eccentric viewing position as a track. The drift or scotoma track moves the average viewing position towards more peripheral or hyper-eccentric retina with poorer acuity. A drift or nystagmus track of 60 minarc would position the eccentric viewing point as much as twice as far away from the target as necessary, for example, with a 120 minarc radius scotoma.

Steinman and Cunitz (1968) detected such drift eye movement while two subjects used eccentric viewing with a physiological scotoma and implicated them in the fluctuating visibility of targets first noticed by Simon (1904). They suggested that the drift movements were directed towards a target disappearance point and that the drift mechanism is guided by some retinal architecture or normal motor habit for fixation control. Whittaker, Budd and Cummings (1988) found drift eye movements with scotomas in three more subjects and showed that drift slow phase can be consistently towards other directions than the target, i.e., the normal fixation locus. Whether drift was target directed or not was idiosyncratic.

Bertera (1990) and Bertera (1991) measured eye movements during the early scotoma adaptation period and found repeated drift movements with normal subjects with simulated scotomas. Five subjects emitted drift eye movements with saccadic returns, but only after the initial period of adaptation when error saccades were minimized and the eccentric viewing position "settled down" to a stable vantage point. All the subjects showed periods exclusively of drift which brought the scotoma edge near an optimum position to the target followed by saccade returns, similar to jerk nystagmus. The target directed drift movements were strategic since they often ended before the scotoma actually obscured the target. This subject shows a typical drift amplitude of about one degree. The drift velocity ranged from 20 to 120 minarc/s. Drift was a significant portion of the total viewing time, averaging 58%.

At ARVO 1996 Dr. Lou Dell'Osso presented work on what he termed "braking saccades" that he began in 1977. These braking saccades may serve to supply a stop action or brake to nystagmus movements. This is a modest confirmation of the utility of the method proposed for the Image Shift system in countering drift produced by foveal visual loss. While congenital nystagmus and scotoma nystagmus might arise from different processes, controlling their associated drift movements might take a similar form. We are pursuing the possibility with Dr. Dell'Osso of further avenues of research and application.

Hyper-eccentric viewing with steady fixation and saccades.

Marked individual differences exist in the development of eccentric fixation among subjects but large excursions away from the target (hyper-eccentric fixations) are clearly represented in mean eccentricities for eye positions across subjects. Hyper-eccentric adaptation to scotomas has the effect of enlarging the scotoma so that the spot size on the retina is an underestimate of the impairment.

Adaptation of saccades compared to steady fixation

Saccades are affected quite differently from steady fixation by a scotoma. If a subject tries to steadily fixate a single stationary target in peripheral vision there are two processes which must be accounted for. Adjusting the eye position in small trial and error increments until the target is visible near the scotoma edge is required as the first step. Once an alignment of the target has been achieved the subject may need only to inhibit the reflexive tendency to fixate the target with the scotomatous fovea. However, if the target is moving, either smoothly or in jumps, subjects must update their eye position with saccades to maintain an optimum eccentric viewing position.

When the target moves, e.g. once per second, the subject is required to make a series of saccades where each landing or fixation has three requirements: 1) detection of the new target position, 2) programming a saccade of the right length depending on the current eye position, and 3) landing and checking if the target is outside of the scotoma boundary (i.e. visible outside of the scotoma). Heinan and Skavenski (1992) addressed this problem in an animal model by ablating the fovea bilaterally in monkeys. When required to maintain a steady eccentric view to a single stationary target adaptation of fixation position was rapid and the animal was able to maintain the target outside of the scotoma boundary, much like the human subjects with a simulated scotoma (e.g., Bertera, 1990; Whittaker and Budd, 1988). However, in a second saccade tracking task, the target shifted around the display requiring repeated saccades to maintain the target in view outside of the scotoma. Here the subjects showed little adaptation and continued to make foveations with the scotoma area. It seems that fixation adapts but saccades do not. The reason probably lies in the processes of computing a landing position in the periphery and in defeating the reflex to land with the fovea, which must be accomplished just before the saccade starts.

Purpose of present work. Objectives

Technical objectives of the Phase II work; are:

1. To refine and construct an experimental prototype of an image shifting system with the following components:

    a) A software algorithm to identify, copy, and shift the foveal visual image to peripheral retinal locations.

    b) Software controls to allow variations in spatial and temporal display parameters to be used as independent variables, including the:
    i) size of the scotoma
    ii) size of the image shift area, if larger or smaller than the scotoma

iii) delay of the image shift relative to eye fixation or current eye position, i.e., the delay between a fixation change and image shift.
iv) delay of replace function, i.e. delay between fixation change and delete of shifted image, and replacement of target to its true location.

2) To further develop visual tasks which approximate the demands of target acquisition and recognition and promote systematic testing of the image shift method. Three tasks will be used for determining the effect of image shifting parameters (1.b) and they consist of:
   a) a fixation task
   b) a two target alternation task
   c) a saccade tracking task

3) To evaluate the image shift system parameters (1.b.) and visual tasks (2.a., 2.b., & 2.c.) within a scotoma simulator that will allow a broad test of image shifting as a compensation for visual loss under different task demands.

The automated image shift method addresses two important impairments resulting from a central field scotoma. First, the scotoma blocks information usually accessible to the fovea so that a target is completely missed when it is hidden inside the scotoma area. Second, central scotomas produce slow drift, and reflex foveations that place the target within the boundary of the non-seeing scotomatous retina. The drift is associated with a "scotoma nystagmus" that pushes targets even farther into the lower resolution periphery. Reflex foveations with the scotoma, called “scotoma fixations” are difficult to eliminate even after extensive practice at eccentric viewing (Bertera, 1991) probably because of the over learned sequence of directing attention to periphery followed by foveal fixation.

An objective in this project is to determine the best parameters for image shifting without triggering unwanted reflexive movements during the repeated process of shifting that might reduce the efficiency of image shifting as a compensation for central visual loss.

The cost and complexity of an electronic system could be reduced by using residual function to minimize the key problems of scotoma fixations and locating the eccentric fixation position. A “braking saccade” first described by Dell'Osso procedure is being explored to reduce drift. The braking effect serves to shorten the principal eccentric fixation by requiring a saccade to stop drift movements before they develop.

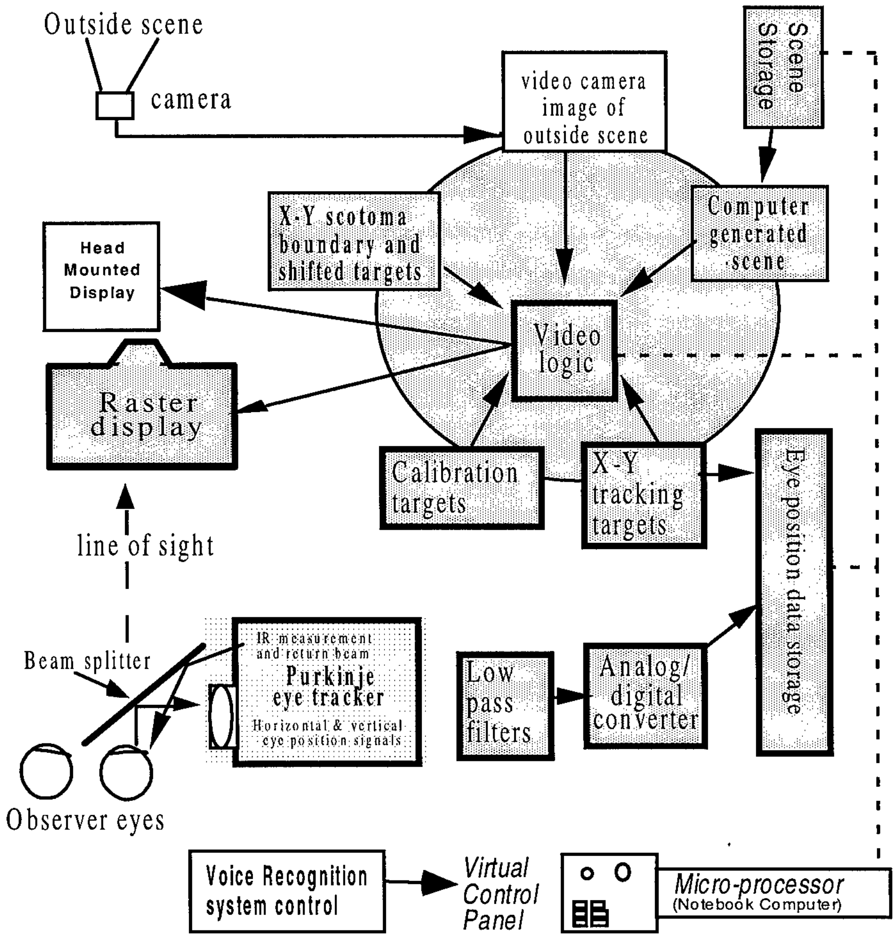


Figure 2. The Image Shift system was mocked up with a 19" raster display driven by a micro-processor graphics controller. Monochrome and color visual scenes presented on the raster display were over layed with a simulated scotoma and a shifted image corresponding to the area around the fovea (see text). Eye position data were recorded from a Dual Purkinje tracker. Size and position of scotoma and shift image were altered via a disk resident file. (Darkened elements have been mocked up as of Ocotober 1996)

METHODS

Hardware and software elements of the image shift system

Central processing unit

Central processing units in microprocessors are increasing in speed and commonly operate at 66-200 MHz for currently available Pentium processors. The prototype development was directed to follow the path of the increasing CPU and graphics speed and to capitalize on the inherent speed and cost reductions of the PC industry. During the 1996-1998 period it is likely that notebook sized computers will operate from 133-250 MHz. These higher speeds will make it feasible to move 300 pixel square areas within the visual display space as well as to scale contrast levels within a shifted image so that most of the information about target identity will be preserved. The image shift prototype software was tested in a 66 MHz PC and a 166 MHz PC with a desk top visual display.

Image Displacement Method

A pixelated video raster image (selected for development in this project) and an optical image displacement with a mechanical scanner are two general strategies for rapid image shifting or translation in the visual field. A video system has the advantage of wide potential for image processing operations as well as image translation across the visual field. Movements of a video image can be performed as rapidly for a five degree shift as a one degree shift. Also, it seems reasonable to expect implementation of additional visual information through an image shift display, thereby integrating it with normal operations and display requirements. By comparison, a motor driven or mechanical scanner used to deflect an image will be susceptible to at least some inertial effects, lowering the bandwidth for shift as well as artifacts caused by vehicle movement and vibration.

A test system for the Image Shift and scotoma simulator functions is being developed and implemented on a full sized microcomputer system and the system components are included in Figure 2. The design of the Image Shift system includes a computer controlled visual display to present the shifted visual targets and background visual scene, along with a simulated scotoma for use in the test phase. The visual display used for the eye movement associated tests is a maximum of 30 degrees wide and is driven from video logic and memory with computer generated images of the visual scene and shifted images, along with calibration and tracking targets. In the development system a second smaller display is used as a virtual control panel for setting and controlling system parameters.

Eye Position Measurement

Eye movements were measured with the dual-Purkinje Tracker which is a non-contacting eye movement measuring system (right eye) and scotoma positioning accuracy is better than 5 minarc. Horizontal and vertical eye position signals, filtered from 60-100 Hz (low pass) were sampled at 120-200 Hz and eye fixations were defined by eye position sample sets that remain within a 20 minarc area for 100 msec minimum. Fixation duration is summed for fixation sample sets in msec and stored (for off line analysis). The head is stabilized with a bite plate. Head stabilization allows smaller scotomas to be positioned accurately near the fovea. Calibration signals were used to relate the analog Purkinje tracker eye position signals to visual display coordinates and post trial calibration was typically checked about 70% of the time. The eye movement analysis program runs off line, gathers a series of files containing eye movement and manual response data, as well as a recording of the various condition codes for each trial. A linear trace of the horizontal and vertical eye position was plotted to check for drifts, fixations, and saccades, along with a point plot of eye positions overlaid on a sketch of the target array for each trial.

Procedures

The objective for the preliminary tests was to generate data using image shifting under a variety of scotoma and visual task conditions which could be used for design revisions. An eccentric viewing task was implemented by displaying a series of targets on the visual monitor and requiring the observer to hold an eccentric position so that the simulated scotoma boundary was positioned off of the target. The visual targets consisted of scanned scenes of terrain and simpler numeric displays with >1 degree separations between the horizontal array of numerals.

Most of the tests were simplified by substituting cursor movements from a hand operated mouse for eye positions read from the analog eye position sensor. The cursor could be steered, drifted and jumped around the display to mimic the human eye to test the effect of the coordination of the simulated scotoma movement and the shifting images. The cursor, like an eye fixation, could approach targets from different directions and speeds to test for perceptual effects of the close coordination of the disappearance of the target within the scotoma at each "fixation" and the closely coordinated image shift and appearance in the periphery. The cursor simulation also addressed the objective of developing a system that could be used for demonstrating the effect of a scotoma in obscuring visual targets as part of a training procedure in understanding scotoma effects and in learning eccentric fixation.

Branching was implemented among image shifting for static targets scenes, pursuit of moving targets, and finger pointing at target locations. The static target and moving target modules were directed to examining image shifting for the two types of eye movements which might be required in typical work requirements. The finger pointing task was used to address the issue of an appropriate manual response measure to use in measuring performance and spatial adaptation during image shifting. Within each program branch, software was developed for control buttons (on the visual display) for setting image shifting parameters, selecting data recording and target files, eye position sensor functions, and experimental trial structure.

Within the image shifting branch for static targets, a static image was retrieved from a disk resident file to serve as a snapshot of the current real world scene. On this base screen image three smaller images could be overlaid:

1) A scotoma image consisting of a selectable bit mapped graphic that was overlaid as an opacity (an absolute scotoma) on the base terrain scene or numeric array. The scotoma image can be constructed as a positive (lighter than the underlying image background) or a negative (darker than background). The horizontal and vertical size of the scotoma and its and its horizontal and vertical displacement from the foveal fixation point is selectable from on screen panels.
2) The shifted image is composed of a copy area and a re-display or transplant area. Both horizontal and vertical image sizes are set from a panel and currently must be the same size.
3) A pair of designator images, small filled circles (10 minarc to 30 minarc in diameter), were used to cue to rhythmic saccade pattern. The designator placed on the target was larger than the designator placed at a peripheral location.

Within the pursuit branch for moving targets, a monochrome target image was generated (later to be retrieved from a disk resident file) to serve as a tracking signal. The tracking signal and background can be presented in a positive or negative contrast relationship. The signal is ramped across the screen at varying velocities, different start points, and left vs. right direction. The objective of using this branch is to determine the maximum target velocities that might be used with an image shifting or eccentric fixation method.

Within the finger pointing branch, a target is presented at a fixed position and the subject is required to point to its remembered location. Under normal conditions, good correspondence is typically found between the target position and finger position. The finger pointing branch will allow testing spatial location errors that emerge after a period of adaptation with the simulated scotoma and image shifting in normal subjects. Such errors might be due to changes in the spatial mapping of retinal position relative to eccentric viewing position and the mapping of manual response relative to the eccentric viewing position.

RESULTS AND DISCUSSION

The software development includes a virtual control panel for image shifting and experimental control is shown in Appendix B.1. The important features are selection of branching to the three experimental modules for image shifting shown in the upper right, moving targets and finger pointing along with online alteration of the disk resident control file for scotoma size, image shift area, and scotoma and image positioning. The target images can consist of any bit mapped image that is specified in the text box marked “image file” in the first program control frame. The panel shown is a simple numeric array (shown in middle “display window”) but can include pictures of terrain, terrain and overlaid maps, or instrument panels. The next panel includes controls for eye position recording, analog eye position sensor calibration, verification for accuracy, and trial storage. This panel controls also include settings for image copy and transplant positioning relative to the fixation point.

The bottom two panels are 1) right, A panel used to set initial values for analog position sensors, hand position sensor, and to check the value of status indicators from sensor hardware, 2) left, A window for editing image control and experimental variables during the course of a data gathering session. These data are shown in Appendix B.2 for an image shifting protocol with, for example, number of samples (for eye position)=2000, Horizontal and vertical shift image radius of 60 minarc, a subject to sensor distance of 600 mm and eccentric fixation markers located at 20, 140 (X&Y) and 40, -30.

A typical test of the image shifting branch included 24 trials of 2000 samples each for eye position recording. Variations were included for simulated scotoma size (10-300 minarc) as well as copy and transplant areas for image shifting (10-300 minarc), the visual display (numeric array or terrain image). Combinations of large scotoma, large shift image and complex display (high resolution, 1024X600, with 16 bit color depth) reduced sampling rate to approximately 100 Hz. This was due to the slower processing speed for the Visual Basic (Microsoft) language used for this prototype software.

The simulated eye position input was used to pass data through the image shifting and data collection and recording system. A sample of the data files produced in a single trial is shown in Appendix B.3. Each trial is marked with time of day, the settings file used to control the trial, horizontal and vertical minarc per pixel at the selected subject to sensor distance in mm, the blink and track status reports from the eye position sensor, and the horizontal and vertical eye position. Samples just before and after and eye blink can therefore be isolated. The data for a simulated run with a mouse cursor serving for eye position input is shown below for “looking” between two eccentric fixation points along a diagonal line eccentric to a target.

Figure 3. Eye Position Sample during Simulated Rhythmic Saccades

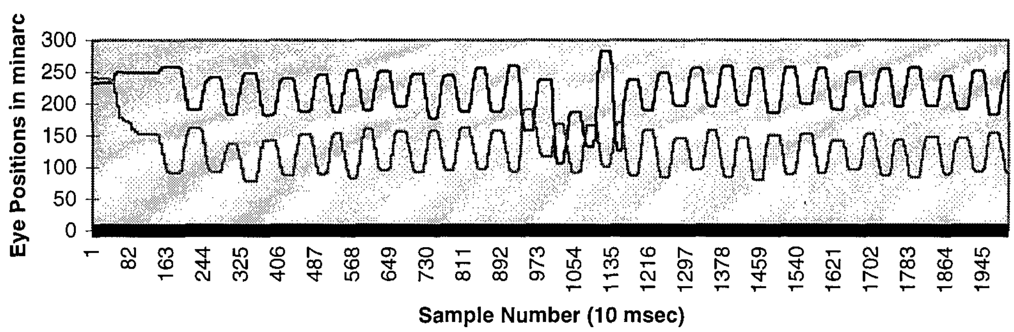
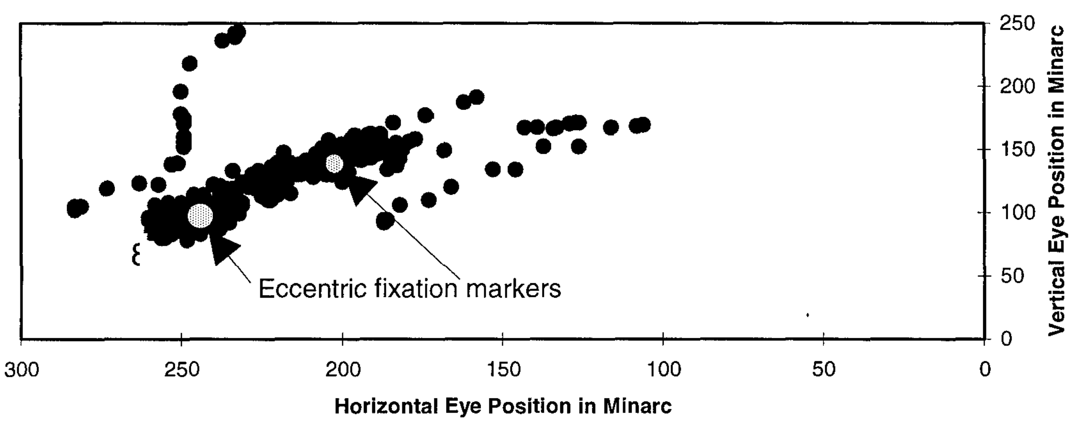


Figure 4. X-Y Eye Position Plot for Simulated Two Saccade Alternation



Several technical improvements during 1996 should have a positive impact on the design and development of electronic visual aids. Head mounted visual displays and miniature Liquid Crystal Displays have improved in resolution and image contrast (See Appendix A). Computer power has continued to fall in price. Intel and other CPU makers continue to project increases in CPU speed beyond 200 MHz.

Projected technical improvements in the image shift system for the 1996-1997 period include inserting a compiled version of the image copy routine to improve the frequency response of the system. Narrowing the visual field with lenses, denser LCD elements, or CRT amplifier adjustments can be used to improve resolution without slowing the graphic processing functions. The image shift software will be tested in a notebook sized computer along with the head mounted display to explore problems in eccentric fixation control under head mobile conditions. Voice recognition software has the speed of recognition and accuracy, for small vocabularies at least, that is sufficient for “hands off” control of a prototype HMD system. We explore this possibility because it will add value to the prototype image shift system whether it is tested in a desk top or notebook computer system.

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APPENDIX A. HEAD MOUNTED DISPLAYS & OTHER APPLICATIONS

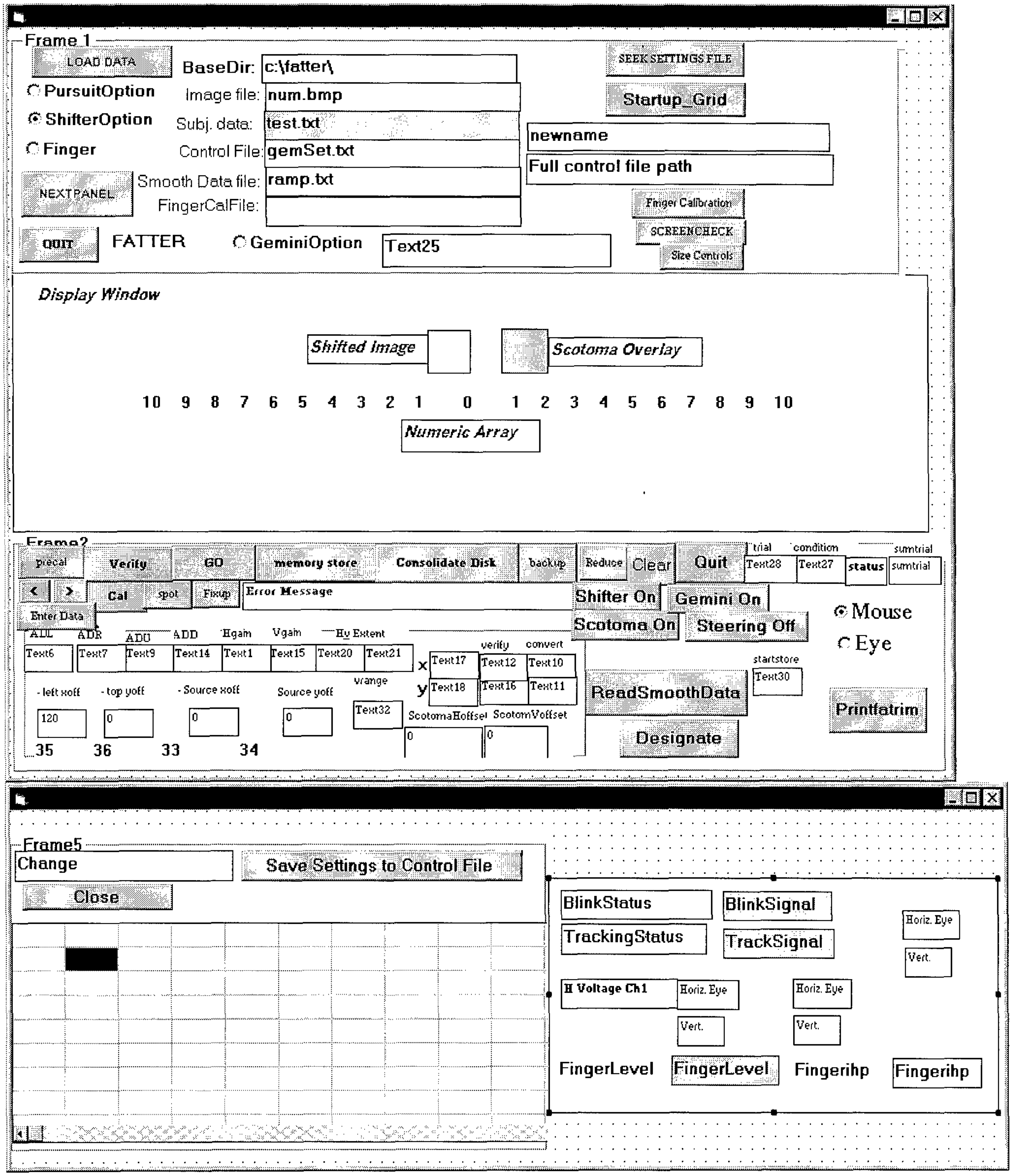
Technical improvements during 1996 and projected for 1997 should have a positive impact on the design and development of the image shift system. Head mounted visual displays and miniature Liquid Crystal Displays have improved in resolution and image contrast to allow a better transfer of visual information through the system. One manufacturer of LCD substrates, Kopin Corporation in Westboro, Massachusetts, also produces head mounted displays consisting of a plastic shell, lenses, LCD substrate and attached microphone for voice input. This program was driven by military applications in the last ten years and has continued with interest in computer controlled visual projection systems.

Kopin has increased the density of LCD pixels in substrate manufacture to 640X480 pixels within a 0.75 inch active matrix display. Further improvements in the density are in prototype stages in October 1996 and 800X600 pixel density with grayscale of 256 should be available in 1997. The Kopin HMD will serve as a low cost implementation of the image shift method which satisfies the need for constructing a prototype visual aid system that is portable and versatile. Development partnerships exist between Kopin and North American Rockwell and CPSI (now the Xybernaut Corp.).

The availability of miniaturized CRTs for military use by Kaiser Electro-Optics, Inc. for head mounted applications (both CRT and LCD) has stimulated a good deal of research activity at several government and non-profit labs. We have contacted several of them for advice and searching for potential research, development and manufacturing partners including Northeastern University, MIT, the Joint Services Working Group on HMDs, and the Human Interface Technology (HIT) Lab, Seattle, Washington. The HIT Lab is developing a laser scanning HMD display to increase display brightness, field of view, and resolution using a head-mounted scanner within a five year time frame. The method of laser scanning the retina directly was first developed to a working prototype at the Schepens Eye Research Institute, Boston, but the commercially available systems are strictly desk top machines. The problems of miniaturization are daunting for a laser scanner HMD, e.g., preserving linearity, reducing bulk, and insuring laser safety for continuous use.

APPENDIX B. SOFTWARE DEVELOPMENT

B.1. CONTROL PANELS FOR EXPERIMENTAL TRIALS & IMAGE VARIABLES



B.2. CONTROL FILE VARIABLES & SAMPLE VALUES.

ZeroROW	empty	empty	empty	empty	empty	empty	empty
NumberSettingRows	130	empty	empty	empty	empty	empty	empty
Subject Data File	c:\fatter\test.txt	empty	empty	empty	empty	empty	empty
ctrldat	20	empty	empty	empty	empty	empty	empty
NumberOfSamples	2000	empty	empty	empty	empty	empty	empty
NumberTargetMoves	2000	empty	empty	empty	empty	empty	empty
GO Button Name	GO POINT	empty	empty	empty	empty	empty	empty
TargetRadiusInMinarc	60	empty	empty	empty	empty	empty	empty
CalTargetRadiusinMinarc	10	empty	empty	empty	empty	empty	empty
horsize	300	empty	empty	empty	empty	empty	empty
versize	300	empty	empty	empty	empty	empty	empty
HorShifterRadiusInMinutes	60	empty	empty	empty	empty	empty	empty
VerShifterRadiusInMinutes	60	empty	empty	empty	empty	empty	empty
HorScotomaRadiusInMinutes	60	empty	empty	empty	empty	empty	empty
VerScotomaRadiusInMinutes	60	empty	empty	empty	empty	empty	empty
empty	empty	empty	empty	empty	empty	empty	empty
totcond	1	empty	empty	empty	empty	empty	empty
Start Trial	1	empty	empty	empty	empty	empty	empty
Start Condition	1	empty	empty	empty	empty	empty	empty
SubjectDistanceInMM	600	empty	empty	empty	empty	empty	empty
BlinkOnLevel	7777	empty	empty	empty	empty	empty	empty
TrackLossLevel	4080	empty	empty	empty	empty	empty	empty
Num Cal Samples	200	empty	empty	empty	empty	empty	empty
Cal Delay # Loops	200000	empty	empty	empty	empty	empty	empty
LineLength in mm	51	empty	empty	empty	empty	empty	empty
Short Delay	0	empty	empty	empty	empty	empty	empty
Image File	c:\fatter\scotimg.bmp	empty	empty	empty	empty	empty	empty
Change	C:\BAFB\LEAN\	empty	empty	empty	empty	empty	empty
Smooth Data File	C:\fatter\smootha1.txt	empty	empty	empty	empty	empty	empty
Fingerange	1024	empty	empty	empty	empty	empty	empty
FingerCalFile	fingcal.txt	empty	empty	empty	empty	empty	empty
StartControlRowMinus1	47	empty	empty	empty	empty	empty	empty
empty, Line # 40	empty	empty	empty	empty	empty	empty	empty
cgrid$ Line 46	empty	empty	empty	empty	empty	empty	empty
Condition	Trial	Alltrials	x1Minarc	y1	x2	y2	StimDur
1	1	1	200	140	40	-30	77
1	2	2	300	140	40	-30	77
1	3	3	400	140	40	-30	77
1	4	4	600	140	40	-30	77
1	5	5	700	140	40	-30	77
1	6	6	200	140	40	-30	77
1	7	7	300	140	40	-30	77
1	8	8	400	140	40	-30	77
1	9	9	600	200	400	300	77

B.3. EYE POSITION & MANUAL RESPONSE DATA FILE & SAMPLE VALUES.

Header lines	20		
Number of samples=	2001		
Time of day	10:51:33		
Date	10/4/96		
Settings file	c:\fatrim\gemSet.t xt		
Stimulus file	ramp.txt		
Start Condition	1	Start Trial	1
Stimulus size	0		
left signal X position		Y position	
right signal X position		Y position	
target name	targetname$		
Timer Totals		timer rate cps=	0
Horiz. minarc/px=	2.19179	Vert. minarc/px=	2.19179
sampling rate 0			
Blink>XXXX is Blinking space	7777	Track < XXX = TrackLoss	4080

Condition#=	1	Trial#=	1	AllTrials#=	1	Stim1 Hpos	200	Stim2 Hpos	40	S

H EyePos	V EyePos	KeyPress	Target	Blink	Track	FingerPos (minarc)
232	243	0	0	444	555	0
232	243	0	0	444	555	0
232	243	0	0	444	555	0
232	243	0	0	444	555	0
233	242	0	0	444	555	0
233	242	0	0	444	555	0
233	242	0	0	444	555	0
233	242	0	0	444	555	0
233	242	0	0	444	555	0
233	242	0	0	444	555	0
233	242	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0
233	240	0	0	444	555	0

DEPARTMENT OF THE ARMY
US ARMY MEDICAL RESEARCH AND MATERIEL COMMAND
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Rec'd 7/19/2000

REPLY TO
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MCMR-RMI-S (70-1y) 6 Jul 00

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Phyllis Rinehart

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